Morphological selection in phase separation of a lyotropic liquid crystal

— The role of smectic order —

Institute of Industrial Science, Univ. of Tokyo
Yasutaka Iwashita[1] and Hajime Tanaka

相分離は、ヘテロな空間構造を形成するうえで最も基本的な物理現象の一つである。しかし多くのソフトマターのようにメゾスケールの内部秩序を持つ系の相分離に関しては、幾つかの興味深いパターン形成が報告されているものの、その秩序が相分離キネティクスに与える影響については未だ十分に解明されていない。本研究ではリオトロピック液晶のラメラ (スメクチック) - スポンジ (等方) 相分離を用いた実験を行い、基本的な (低次元の) 秩序であるスメクチック秩序が相分離パターン形成においてどのような役割を果たすか調べた。その結果スメクチック秩序と相分離のキネティックな競合により、ネットワーク、フォーム、ドロップレットといった全く異なる空間構造が形成され得ることを示した。

Phase separation is one of the most fundamental physical phenomena that produce heterogeneous structures in a self-organized manner, e.g. foam polystyrene is formed by gas-polymer phase separation. For the phase separation of a binary mixture of simple fluids, its mechanism and kinetics has been elucidated theoretically and experimentally [e.g. [1]]. However for the phase separation of a system including a mesoscopic internal order such as smectic one, which is the essential feature of soft matter, the role of the order in the kinetics of the phase separation has not been clarified well, whereas it has been reported that interesting pattern can be formed in the process. In this paper we study how the smectic order, which is an elemental (low-dimensional) order, affects the kinetics of phase separation of an ordered (smectic) phase into the coexistence of the ordered and a disordered (isotropic) phase.

The sample which we used was a lyotropic liquid crystal $C_{10}E_3/H_2O$. We directly observed the phase separation process of the lamellar (smectic) phase into the coexistence of the lamellar and sponge (isotropic) phase in real-time with optical microscopy. As a result, we found three characteristic morphologies with respect to the concentration ϕ and heating rate Q (Figure 1(g))[2]: Transient network (Figure 1(a)(b)), stable foam ((c)(d)) and droplet structure ((e)(f)). Together with other results and analyses, we demonstrate that the kinetic interplay between

[1]E-mail: iwashita@iis.u-tokyo.ac.jp

phase separation and smectic ordering is a key to the morphological selection. Our findings may provide a new route to the formation of network and foam morphologies in soft matter.

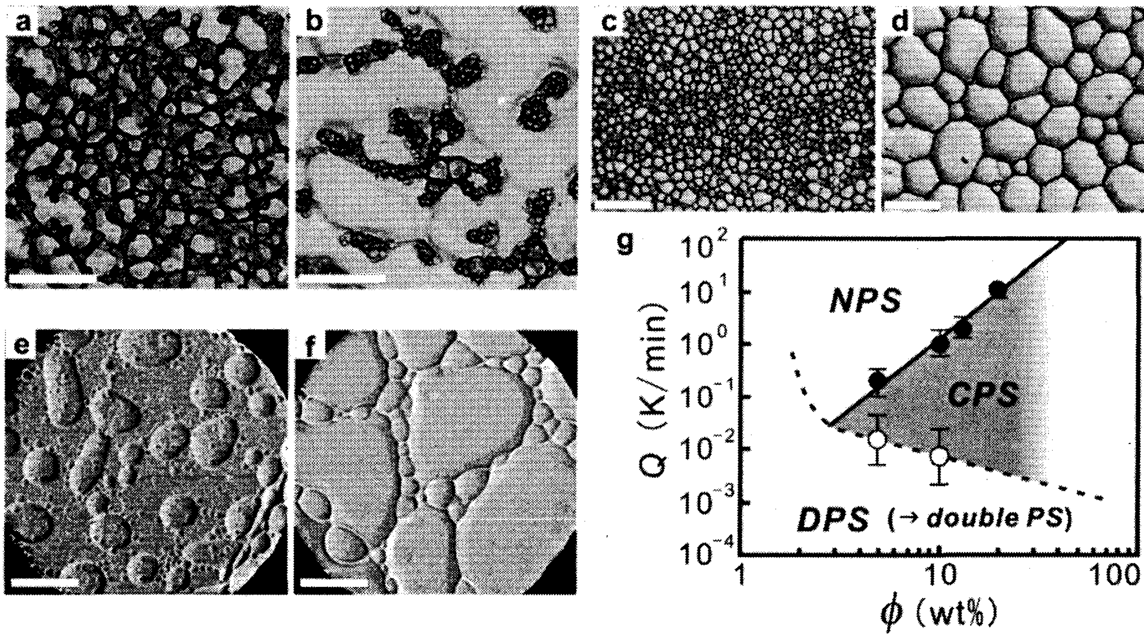

Figure 1: (a) and (b): A transient network pattern (a) coarsens to (b) with time. (c) and (d): A foam pattern (c) coarsens to (d) with the temperature rise. At a constant temperature this foam is fairly stable. (e) and (f): A droplet pattern of sponge phase (e) evolves to (f). All the scale bars correspond to 500μm. (g): Morphology diagram in the plane of the heating rate Q and the concentration (ϕ). NPS (network phase separation) denotes the region where the transient network of the lamellar phase is formed, CPS (cellular phase separation) does the region where the foam of the lamellar phase is formed and DPS (droplet phase separation) does the region where the droplets of the sponge phase is formed. For each concentration a sample was heated at a constant rate Q to the same temperature at which the lamellar phase is the minority phase.

References

[1] A. Onuki, *Phase Transition Dynamics* (Cambridge university press, Cambridge, 2002).

[2] Y. Iwashita and H. Tanaka, *Nat. Mater.* **5**, 147 (2006).